Therefore, the Hatfield models do not properly reflect the costs that would occur for either scenario. This creates a significant underestimation bias in the models results.

Q. DO THE HATFIELD MODELS ASSUME FICTITIOUS CABLE ROUTES?

A. Yes, the Hatfield models, by utilizing inputs from the Benchmark Cost Model assumes that census block groups (CBGs) are square in shape, are assigned to the wire center closest to the centroid of the CBG, that feeder routes extend to the nearest midpoint of a side of the assumed square perimeter of the CBG (or penetrate 1/4 of the length of a perimeter side into the square CBG). These assumptions do not reflect actual customer locations. It is also not clear that the models even reflect the costs of serving an area which has uniformly distributed population (a stated assumption).

Q. ARE THERE OTHER PROBLEMS WITH THE HATFIELD MODELS?

A. Yes, there are. I have simply listed below some of the factors in the Hatfield models which are unrealistic, imprecise, may lead to certain problems and errors, or are simply wrong:

- Possible underestimation of BellSouth North Carolina service territory by misassignment of CBGs, miscalculation of areas and/or missing CBGs.
- Assignment of CBGs to the wrong wire centers.
- Assignment of CBGs to the wrong serving LEC.

- Problems related to CBGs served by multiple wire centers and/or multiple LECs.
- Labor and switching cost inputs may be substantially understated.
- Operating expenses may be understated via cable cost multipliers.
- Fill rates for feeder and distribution cable appear unrealistically high leading to unrealistically low costs.
- Fill rates appear to be higher than stated in the models documentation.
- Implied fill rates for serving area interface (SAI) and multiplexing (MUX) appear unrealistically high.
- The models appears to be unwieldy and difficult to run.
- The source for manhole, terminal, splice and serving area interface and other costs appear to be based on "subject matter" expert judgment without documentation or validation.
- The identification of subject matter experts (SMEs) utilized by the models is not clear.
- Where and how SME expertise was utilized is not clear.
- Switching costs appear substantially understated.
- What would be expected as major changes in the model do not lead to major changes in the results of the model.
- The models do not reflect the additional costs of changing facilities which exist in a growing demand environment.
- Cost of money and depreciation costs may be unrealistically low.
- Costs for digital cross connects, SS7 network components and essential network support systems may be excluded or understated.

• Operator position costs appear understated.

Q. DO THE HATFIELD MODELS PRODUCE RESULTS WHICH ARE CONSISTENT WITH THE CURRENT COSTS OF PLACING FACILITIES?

A. No, it appears they do not. For example, engineer James Schaaf, testifying on behalf of Pacific Bell in R-95-01-020 (the universal service cost proxy models docket) in his testimony filed April 17, 1996, considered the Hatfield results and a detailed prospective evaluation of the actual current/prospective costs for Angels Camp, California. Mr. Schaaf stated:

> The results of the study are that the BCM Hatfield results in a $28,767 total cost for 12,376 feet of feeder distance. This is <u>$2.32</u> per foot. ... The results of the real world estimation process is $140,043 total cost for the same distance of feeder or <u>$11.32</u> per foot. As anyone can see, the results of the BCM Hatfield are highly problematic. (Emphasis in original).

Q. WHAT ARE THE BCM AND BCM2 AND HOW ARE THEY RELATED TO THE HATFIELD MODELS?

A. The BCM was developed initially "to identify those CBGs [census block groups] in which the cost of providing basic telephone service is so high that some form of explicit high-cost support may be necessary as part of a universal service solution."[22] as a tool to evaluate the need for universal service funding. The Hatfield models utilize the BCM or variants of the BCM for manipulation of demographic data, especially for critical loop investment calculations. However, the BCM was widely criticized as suffering from severe problems that yielded unreliable and unrealistically low cost estimates. By early 1996, the sponsors of the BCM recognized its major shortcomings and stated that work was underway to correct these major shortcomings. By July 1996, the two remaining sponsors of the BCM, USWEST and Sprint, released BCM2 and a set of BCM2 results for all states. BCM2 appears to have corrected the major flaws inherent in the original BCM.

Q. WHAT ARE THE BCM2 RESULTS FOR NORTH CAROLINA?

A. The statewide average monthly cost for basic local exchange service is $<u>34.22</u> in the BCM2 results.[23]

Q. WHAT IS THE COST PROXY MODEL (CPM)?

A. The CPM is a model jointly developed by Pacific Bell and INDETEC International. It enables companies and regulators to quantify the cost of

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22 "Benchmark Cost Model," A joint submission by Sprint Corporation and USWEST, Inc in CC Docket No. 96-45, July 3, 1996, p. 2.

23 Id.

providing universal service. The CPM is based on a consistent, uniform unit of geography, separates operating expenses from investment, separately develops structure costs and accounts for efficiency of the LEC. In my opinion, the CPM is based on sound economic, financial and management accounting principles.

Q. DOES THE CPM YIELD RESULTS THAT ARE SIMILAR TO BCM2?

A. Because of the corrections from the BCM1 version, the BCM2 now yields results which are similar to the Cost Proxy Model, even at geographic levels as small as a wire centers.

Q. MR. WOOD CONTENDS THAT MANY OF THE ENHANCEMENTS TO THE BCM2 ARE PRESENT IN THE LATEST VERSION OF THE HATFIELD MODEL.[24] IF CORRECT, WOULD THIS CHANGE YOUR RECOMMENDATION?

A. No. Saying that the Hatfield Model is "new and improved" is far different from demonstrating its superiority to other models. First of all, the new version of the Hatfield Model has not undergone the type of regulatory and other rigorous scrutiny that are normally applied before a model can be adopted for purposes of public policy and rate setting. Therefore, using the most recent version of the Hatfield Model to estimate the incremental costs of BellSouth's unbundled network elements is not legitimate until the critical underlying BCM Plus model

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[24] Direct Testimony of Don J. Wood on Behalf of MCI, Docket No. P-141, Sub 29, at page 4.

has withstood a thorough formal investigation. Despite Mr. Wood's reassurances, the latest revision to the Hatfield Models is brand new and untested. In my opinion, this arbitration proceeding is not the place to be introducing new primary cost models. Until the BCM Plus loop cost model is proven superior to other loop costing models, the Hatfield Models should not be used by the NCUC.

Q. DID THE FCC RELY ON THE HATFIELD MODELS AND THE BENCHMARK COST MODEL (BCM) TO DETERMINE THE LEVELS OF ITS LOOP COST PROXIES?

A. No, the FCC utilized the Hatfield and BCM models only to scale the proxy levels across states. The FCC Order states:

> Based on our current information, we believe that both these models are based on detailed engineering and demographic assumptions that vary among states, and that the outputs of these models represent sufficiently reasonable predictions of relative costs differences among states to be used as set forth below to set a proxy ceiling on unbundled loop prices for each state. *We do not believe, however, that these model outputs by themselves*

> *necessarily represent accurate estimates of the absolute magnitude of loop costs.*[25] (emphasis added)

Q. WHAT INFORMATION DID THE FCC UTILIZE IN DETERMINING THE BASE LEVEL FOR ITS LOOP COST PROXIES?

A. In effect, the FCC used the Hatfield and BCM cost estimates to apply the unbundled loop rates established by six states to all other states.[26] These six states are Colorado, Connecticut, Florida, Illinois, Michigan and Oregon. The FCC created its proxy for each state by inflating or deflating a simple unweighted average of the unbundled loop rates approved in these six states. The unweighted average rate was adjusted upward or downward according to whether the Hatfield or BCM cost estimate for a particular state was higher or lower than the simple unwieghted average of the Hatfield or BCM cost estimates for the six benchmark states. Noting criticisms of the Hatfield and BCM models, the FCC concluded:

> "For the purposes of setting an interim proxy, however, we note that the criticisms have been directed largely toward the absolute level of cost estimates produced by the models, rather than the

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[25] The August 1, 1996, Order in the Matter of Implementation of the Local Competition Provisions in the Telecommunications Act of 1996, released August 8, 1996, CC Docket No. 96-98 (hereinafter "FCC Interconnection Order I") at paragraph 794.

[26] FCC Interconnection Order I, paragraph 794.

relative cost estimates across states. Since our hybrid ceiling explicitly scales the model cost estimates based on existing state decisions and uses the model results simply to compute relative prices, we believe that these criticisms do not apply in the present context."[27]

Q. SHOULD THIS COMMISSION RELY UPON THE FCC'S UNBUNDLED LOOP PROXY RATES IN DETERMINING BELLSOUTH'S RATES FOR UNBUNDLED LOOPS IN NORTH CAROLINA?

A. No. The FCC's proxies do not bear a reliable relationship to the incremental costs of providing unbundled loops. The manner in which the FCC derived these proxies is unclear, and the resulting rates may be less than defensible incremental cost estimates. For example, the FCC's proxy rate for North Carolina is $16.71 per month, but BellSouth's estimate of the monthly long-run incremental cost (LRIC) of supplying two-wire, analog unbundled loops in North Carolina is much higher.

Q. DR. GOODFRIEND EXPLAINS THAT THE HATFIELD MODEL ADDS A TEN PERCENT MARKUP TO CAPITAL AND NETWORK OPERATIONS COSTS INTENDED TO REFLECT FORWARD-LOOKING OVERHEAD COSTS.[28] DO YOU AGREE THIS PROCEDURE IS PROPER?

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[27] Ibid., paragraph 795.

[28] Direct Testimony of Sarah Goodfriend on Behalf of MCI, Docket No.P-141, Sub 29, at pages 28 and 29. Testimony of Don J. Wood on Behalf of MCI, Docket No. P-141, Sub 29, at 13.

A. No. Unfortunately, there is no formula which allows one to take incremental cost estimates and allocate shared and common costs to determine a service price. Incremental cost provides the information necessary to establish a floor for service pricing and part of the information to test for cross-subsidization of services.[29] However, incremental cost information by itself is insufficient to establish the upper boundary for pricing or to determine the price of the service itself.

In general, establishing service prices for the full complement of services a firm offers requires three types of information: 1) incremental cost (establishing the lower boundary for the price); 2) market/demand information; and 3) the total shared and common costs of the firm (establishing the total level of contribution required from all services in total to sustain the firm in the long run).

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes it does.

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[29] Service demand and revenue information provides the other source of information for testing for cross-subsidies.

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MARGINAL COST TECHNIQUES FOR TELEPHONE SERVICES: SYMPOSIUM PROCEEDINGS

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THE USE OF ECONOMETRIC ANALYSIS IN ESTIMATING MARGINAL COST

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THE USE OF ECONOMETRIC ANALYSIS IN ESTIMATING MARGINAL COST

INTRODUCTION

Estimates of marginal cost are important in pricing telecommunications services. For example, economic efficiency dictates that prices be set as close as possible to marginal cost. Marginal cost-based pricing is particularly important in competitive markets. Pricing below marginal cost in such markets will bring charges of predatory pricing while prices set too far above marginal cost will result in uneconomic bypass. For these reasons, estimates of marginal cost should be a key focal point of rate regulation.[1]

How should marginal costs be calculated? Typically, telephone companies have used engineering models. These models describe the components of equipment needed to meet specified demands. From them, marginal costs can be derived by examining the effect of small variations in output on equipment requirements and assessing the capital and operating cost of this equipment. For example, models have been developed which describe the switching equipment needed to meet any specified level of demand. Marginal switching costs can be estimated from these models by comparing the cost of equipment needed to meet alternative levels of line and usage demand. A recent study by Bridger Mitchell describes the engineering approach to cost estimation and provides some estimates of marginal capital costs for loops and switches.

Another approach, described here, would be to estimate marginal cost econometrically. Observed data on costs incurred and outputs produced in specific locations or time periods would be used to estimate cost functions from which

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[1] Many commissions have recognized the importance of marginal cost to the regulatory process. A recent decision by the Maryland PSC affirmed the efficiency gains from marginal cost pricing. There have recently been hearings on calculating marginal cost in Massachusetts, Maine, Connecticut and Delaware.

estimates of marginal costs could be derived. This approach can be useful in three ways. First, engineering models require judgment about installed capital and operating costs. These judgments are particularly difficult for estimating operating costs which may vary from time to time and from office to office. Econometric estimates could be used to test the plausibility of the assumptions used in engineering models. Second, some components of telephone cost are not easily amenable to the use of engineering models. This is true, for example, for managerial and professional overheads and marketing cost, which represent nearly 30 percent of total telephone company costs. By using observed data on overhead costs and outputs, the effect of output on these costs can be inferred. Third, the development of an efficient telecommunications system involves a host of complex and interacting decisions, many of which cannot easily be represented in an engineering model. The econometric approach, by relying on observed data to estimate marginal costs, avoids the need for engineering models.

The econometric approach is not an alternative but a supplement to engineering analysis. It can provide additional empirical evidence in support of an engineering estimate, and it can supplement the engineering analysis for some cost components. But, engineering analysis is essential to establish reasonable forms for econometric cost functions and to estimate costs for technologies not yet employed.

ALTERNATIVE ECONOMETRIC ASSESSMENTS

Econometric estimates of cost could be done at various levels of aggregation. For example, statistical analyses can and have been used to relate the costs of specific loops to loop length, loop density, and technology (copper, fiber optics, SLC). Such an approach permits a derivation of loop costs for customers of widely varying characteristics based on actual experience.[2]

Data might also be examined at the central office level. A recent study (Shin, 1987) used data on 350 central offices to relate switch and loop costs to number of access lines served, number of minutes of local and toll usage. This approach is particularly promising because there is a large base of data on costs for offices with widely varying output mixes and technologies.

While these approaches provide relatively precise estimates of component costs, to assess total marginal cost for specific services, the analysis must be done at a broader level of aggregation--a company or a subdivision of a company which operates largely autonomously. This approach permits us to capture costs which are incurred on a system-wide basis.

At the company-wide level, cost functions could be estimated using time series data, cross-section data, or both. The time series approach estimates the cost function by observing changes in output and cost for a single company over time; the cross-section approach estimates the cost function by observing differences in cost and outputs across companies at a point in time. Historically, the time series approach has predominated and has been used to assess the extent of economies of scale, to evaluate the effect on cost of technological change, and to determine the degree of substitutability between the factors of production. (For a review see Kiss, 1986.) However, time series data has not proved particularly fruitful in assessing the marginal cost of specific telephone outputs. The various outputs of interest (access lines, local and toll usage) are simply too collinear to obtain reliable estimates of marginal costs for each using time series data.

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[2] Such an analysis was done to estimate loop costs in recent studies for Massachusetts and New Hampshire. For the Massachusetts study, see DPUC Docket 1731.

Moreover, changes since divestiture may make it difficult to rely upon time series data to estimate cost conditions prevailing today.

CROSS COMPANY STATISTICAL COMPARISON

Here we explore the use of cross-section data to estimate marginal cost at the company-wide level. The use of such data avoids the problems of collinearity observed in time series data and permits us to focus on the post-divestiture period. The basic data set consists of information on 39 companies observed over the four years 1984-1987 (24 Bell and 15 non-Bell companies).[3] For these companies, we related total cost to three major components of output (access lines, local usage, and toll usage) and a measure of the technological mix of the capital stock (percentage of lines served by electronic switching). Statistical analysis was used to estimate the parameters of several alternative cost functions from which we have derived estimates of marginal cost.

The cost measure used in this study is somewhat different from the accounting costs typically reported in annual reports and in reports to the FCC. Although current operating expenses are measured in the same way as they are in accounting reports, capital costs reflect annual cost of using capital which is revalued every year to reflect its replacement value. The replacement value of the capital stock was estimated by determining the distribution of the current capital stock by vintage. The replacement value of these investments was derived by escalating original costs to reflect changes in the price of telephone equipment over this period and reducing the value to reflect the effects of depreciation. Equipment was escalated in value using the telephone plant index published in Bell System Statistical Manual prior to divestiture and available for individual companies after

[3] In this context, Southern New England and Cincinnati Bell are treated as Bell companies.

divestiture. Annual depreciation was estimated at the current average rate observed for each company in the sample (from FCC Form M). The annual cost of this capital stock includes interest, return, and the net effect of physical depreciation and equipment revaluation.

ESTIMATION METHODS

Two alternative cost functions have been examined in this paper. In the first, cost is a linear additive function of three outputs--access lines, minutes of local usage and minutes of toll usage. In the second, local and toll calls are substituted for minutes of use as the determinants of cost. In both functions, to take account of the effect of technology on costs, we allow the coefficient relating local and toll calls (or minutes) to cost to vary linearly with the percentage of switches which are electronic. For the minute equation, the precise form is:

$$\text{Cost} = a + b^*\text{lines} + c^*\text{local minutes} + d^*\text{toll minutes} + e^*\text{electronic minutes} + f^*\ \text{Bell lines}$$

We did not include an interaction between line costs and percent electronic because electronic switching is generally thought to have a greater effect on usage than on line cost and there was too much collinearity to include both line and usage effects in the same model.

This linear additive cost function assumes that each of the outputs requires specific separable capital investments, that the marginal cost of these outputs is unaffected either by the level or mix of outputs being produced, and that each output is produced with fixed proportions of labor, capital and materials. The function allows for scale economies only insofar as there may be fixed cost to operate a phone company which is independent of the output level. While restrictive, these assumptions do not seem unreasonable or inconsistent with engineering analysis of marginal cost. The capital investment needed to produce access and usage includes local loops (connecting customers to the central office) switching equipment and interoffice equipment. In engineering analyses of costs, it is common to view loop costs as an approximately linear function of the number of customers served, switching costs as separable into components driven by lines and by peak usage and interoffice cost as an approximately linear function of peak interoffice usage. Moreover, for a specific type of technology most engineering analyses assume that operating costs are a fixed proportion of capital investment. If this is an accurate view, the linear additive function is appropriate.

Two statistical approaches were used to estimate the parameters of these cost functions. In the first case, cost and output data for each of the years 1984 through 1987 were averaged to produce 37 to 39 observations and these average cost and output data were related using ordinary least squares regression.[4] Data were averaged over these four years to eliminate random temporal variations and hence improve the precision of the estimate.

In the second case, we created a data sample consisting of each company observed in each year (a total of 142 to 151 observations) and a random effects model (see Hausman and Taylor, 1980) was used to estimate the relationship between output and cost for those data. The random effects model assumes that the error term in these panel data consist of two components: one which varies both over time and company and another error which is specific to each company but does not vary over time. The random effects model takes this error structure into account in estimating the parameters of these functions.[5]

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[4] For the calls data, we had 37 and for the usage data 39 observations.

[5] In each case, the random effects model passed both a Lagrange multiplier and Hausman test. The Lagrange multiplier test (Breusch and Pagan, 1979) determines whether the random effects model improves upon the OLS model through correction of heteroskedasticity over the cross-sections. The Hausman test (cf. Hausman, 1978) compares the random effects model with the fixed

MARGINAL COST ESTIMATES

The estimated parameters of the linear cost functions are summarized in Table 1. Several results are immediately apparent. The cost equations account for over 99 percent of the intercompany variation in cost and all of the variables in these equations are significant at the 99 percent level or higher. This suggests that variations in output and technology account for most of the variation in cost across companies, and the effects of outputs and technology on cost are measured with substantial precision from these data. Second, since the intercept term is close to zero (the constant term is typically 5 percent or less of average cost), the equations exhibit approximately constant returns to scale. Finally, the use of electronic switches markedly reduces cost. Electronic local usage is 9 to 48 percent of the costs of electromechanical calls, depending upon which function is used. For toll calls, electronic switching lowers costs by 50 percent. Thus, whereas total costs for the average company was $1.6 billion, annual costs for an all electronic system would be $1.2 to $1.5 billion or 20 to 30 percent lower.

Table 2 summarizes the estimates of marginal cost derived from these equations. For comparability the marginal cost from the call model has been expressed on a per minute basis by dividing the marginal cost per call by the average number of minutes per call.[6] Marginal costs are derived separately for calls served by electronic and electromechanical switching.

Using exclusively cross-section data and the minutes of use model, marginal cost is $31 per access line per month, .2 cents per minute for electronic

effects model; in passing the Hausman test, we may conclude that the parsimony of the random effects model still provides a consistent estimate.

[6] The calls data used here measure the number of originating calls. For the minute data, interoffice calls are measured both at the originating and the terminating switch. Consequently, a 4 minute call will generate 8 minutes of measured usage--4 at the originating and 4 at the terminating switch.

and 2.1 cents per minute for electromechanical local usage. Marginal cost for toll usage is 3.9 cents per minute for electromechanical and 2.0 cents per minute for electronic usage.

When usage is measured by number of calls, the marginal cost of access is lower ($20.94 per month), costs for local usage are higher (3.8 cents per minute for electromechanical and 0.9 cents for electronic switching), while toll usage costs are lower (2.9 cents for electromechanical and 1.4 cents for electronic switches).[7]

When panel instead of cross-section data are used, there are two principal differences. First, access costs are $25 per line in both the minutes and calls models. Second, electronic switching reduces usage cost much less in the panel than in the cross-section data. Electronic local usage costs, which were only 10 percent to 25 percent of electromechanical costs using cross-section data, are 50 percent as large using panel data. This may be because the panel data averages the effect of variations in technology on cost measured cross sectionally and over time. The time period data may reflect the short-term consequences of increasing the percentage electronic which might be expected to be less than the longer term effect observed in the cross-section.

The difference in results between the call and minutes equation have an interesting interpretation. The minute equations results in much lower marginal cost per minute than those based on calls data. This is because, in these data, holding time is either unrelated or inversely related to cost. While this seems counter-intuitive, there may be a simple explanation. For areas with relatively short calls, a larger proportion of calls may be made in the peak period. For

[7] As measured here, the marginal cost of usage reflects the added cost per average minute of added usage. In reality, of course, only busy hour usage affects costs, and this study assumes the same ratio of costs to busy hour usage in each company.

example, systems where average holding times are short have a higher ratio of business to residence lines and business calls are more likely to be made in the peak period. Since costs are driven principally by busy hour rather than total usage, this could account for the difference in results between the calls and minute equation. This problem could be avoided by using peak rather than (or in addition to) total usage as the key cost driver.

COMPARISON WITH ENGINEERING RESULTS

Table 2 also contains estimates of costs derived from an engineering model. (These estimates were calculated from data submitted by New England Telephone for use in a Massachusetts DPUC hearing.) While the econometric estimates are broadly similar to those derived from engineering analyses, they generally suggest higher cost. Thus, the Massachusetts study suggested access costs ranging from $12.5 to $14 per line per month. By comparison, econometric data suggest costs of $20 to $30 per line per month. Engineering estimates are generally closer to the econometric values for usage. For local usage, engineering costs are 1.1 cents per minute for electromechanical and .2 cents for electronic switching. In both cases, these are at the bottom of, or slightly below, the range of econometric estimates.

For toll calls, the engineering estimates were 1.0 cents per minute at either end of the call. These estimates, which assume electronic switching, are at the low end of the range observed econometrically.

Although the econometric and engineering estimates are close for some outputs and some equations, there is a wide gap when all outputs are considered simultaneously. For example, when all outputs are priced at marginal cost, the econometric equation produces total revenues of $1.3 to 1.5 billion for the average company in the sample. By comparison, pricing at the engineering estimates of marginal cost would yield revenues of $634 to $680 million, less than half as much. This reflects the wide gap between engineering and econometric assessments of access costs and the fact that econometric equations with low local usage costs tend to have high toll and access line costs.

Three factors may account for the difference between engineering and econometric estimates. First, the engineering estimates typically include no allowance for system-wide overhead costs which can account for as much as 30 percent of total cost. The econometric analysis implies that these overheads do vary with output and, consequently, need to be included in assessments of marginal costs. The principal effect of this inclusion is to increase marginal cost per access line.

Second, capital expenditures are quite "lumpy" and, hence, engineering estimates often exclude significant components of capital cost which, when viewed from a single central office, appear insensitive to output. For example, a typical digital switch has start-up costs of about $500,000 irrespective of the level of usage or number of lines and, in engineering studies, these costs are not viewed as part of marginal cost. But, where growth in lines or usage ultimately results in the exhaustion of switches, some of these costs are incremental in that added growth will advance the date at which a new switch must be added. If this is the case, startup costs will show up as part of incremental cost in the econometric analysis.

Third, in engineering studies, marginal costs are calculated based on the most recent technology--fiber optic transmission facilities, digital switching, and electronic multiplexing in meeting long loop demands. Although technological mix is also taken into account in our econometric study, the measures are much cruder and only take into account the difference between electronic and electromechanical switching. With more sophisticated measures of technology, the econometric estimate would be expected to more closely match the engineering estimates.

With these factors, differences between the engineering and econometric estimates seem understandable. But these differences nevertheless raise some serious issues. Although the engineering estimates undoubtedly provide more precise estimates of costs for the components on which they are focussed, they may ignore important components of costs incurred at a system-wide level or incurred in a lumpy fashion. On the other hand, while the econometric estimates are broader in scope, they are vulnerable to errors in specifying functional form, describing technology and controlling for extraneous cost factors. Useful estimates of marginal cost may require some amalgam of these two approaches.

If valid, the econometric estimates also reduce the seriousness of a pricing problem which has been inherent in the engineering estimates. Because the engineering estimates of marginal cost have been so low, pricing at marginal cost does not begin to meet revenue requirements. Consequently, to achieve full recovery, prices must be set well above costs. While this can be done efficiently using some variant of Ramsey pricing, such pricing is complicated (requiring estimates of own and cross-price elasticities of demand) and is politically unattractive to regulators. They find arguments that toll prices should be set close to cost while line charges should be set way above costs unappealing, presumably because of the distributional consequences. Although, as we shall see below, pricing at econometric estimates of marginal cost also leads to a revenue shortfall, it is much smaller and, hence, the requisite disparities between price and cost are also smaller. Efficient prices would be similar for both the engineering and econometric cost estimates. Using the econometric estimates, access costs are set in the $25 to $30 per line range because these are the marginal costs. With the engineering, similar charges would be efficient because revenues based on marginal cost will not cover costs and line demands are inelastic. But regulators may find it easier to justify high access on cost grounds than on grounds of demand inelasticity.

MARGINAL AND AVERAGE COSTS

As with engineering studies, the results of this econometric analysis suggests that marginal cost is well below average cost. This is illustrated in Table 3. For the companies in this sample, average costs (as reported to the FCC) are $1.76 billion per year. But, assuming that incremental demands are met exclusively from electronic systems, pricing all outputs at the marginal cost would generate only $1.2 to 1.5 billion in revenues or 20 to 30 percent less. If the effects of digital and fiber optic equipment were taken into account, the disparity would be undoubtedly larger.

For the econometric analysis, this study provides an opportunity to assess the source of these differences. There are three possibilities:

1. Economies of scale
2. Revaluation of capital
3. Technological changes

Since the equations do not exhibit economies of scale, this is clearly not a factor. Differences in the measurement of capital costs also have little impact. Thus, the annual cost of capital used here for the average company was about $600 million. By comparison, nominal capital charges under current accounting treatment would be about $630 million or 5 percent more. Thus, capital revaluation accounts for only $30 million or a 2 percent difference between average and marginal cost. The small effect of capital revaluation may reflect a limitation of the revaluation methods used. While we have taken into account change in construction costs for capacity built in the past, we have not directly considered the effects of new technology on the value of the existing capital stock. Where the development of new electronic equipment has reduced cost, this lowers the value of older electromechanical equipment. As described below, however, this effect is taken into account by the inclusion of percent electronic as a cost determinant.

Virtually all of the remaining difference is attributable to technological change. Thus, if incremental demands were met with the average mix of equipment used in the past, marginal costs would be about 20 percent greater than those forecast with an all-electronic system. Without technical change, this recovery based on marginal cost would yield revenues very close to average cost.

This result is very helpful in explaining marginal cost to regulators. Moreover, it clearly suggests that marginal costs below average costs is not an inevitable outcome of the cost function for this industry. Because, in the past, technological change has driven costs downward faster in telecommunications than elsewhere, marginal costs are below average costs; if in the future the historic trends in productivity slow, the reverse might well be the case.

METHODOLOGICAL ISSUES

This study differs from previous cost function estimation work in telecommunications in several respects. Three main methodological differences emerge: the use of cross-section data, exclusion of input prices and choice of output measures. I discuss each of these in turn.

A. Use of Cross-section Data

The use of cross section data constitutes the principal difference in methodology between this and previous company analyses. We have chosen a cross-section approach rather than a time series approach in order to get significant independent variations in output. Virtually all of the previous studies have used approximately 30 years of time series data for either the Bell System or Bell